Codes and Standards Enhancement Initiative
For PY2004: Title 20 Standards Development

Analysis of Standards Options
For
Residential Pool Pumps, Motors, and Controls

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May 12, 2004

This report was prepared by Pacific Gas and Electric Company and funded by California utility customers under the auspices of the California Public Utilities Commission

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1 Introduction

The Pacific Gas and Electric Company (PG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standards and options for residential pool pumps, motors, and their associated controls.

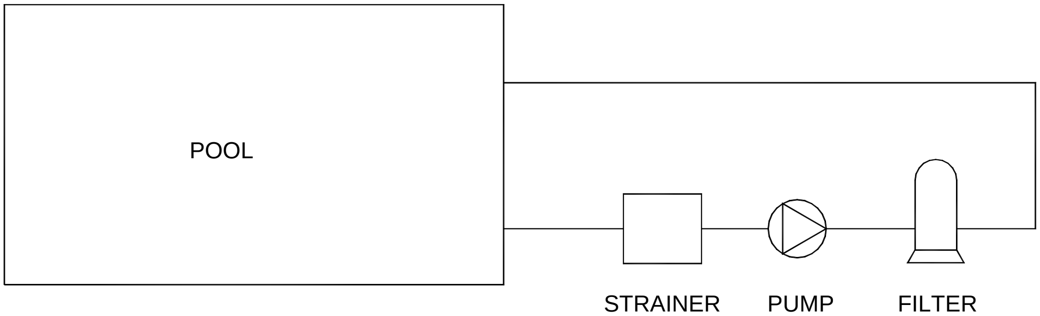
2 Product Description

Residential swimming pool pumps are used to circulate and filter swimming pool water in order to maintain clarity and sanitation. In houses that have them, pool pumps are almost always the largest single electrical end-use, using over three times the energy of a new refrigerator. More importantly, they create a diversified electrical demand over 20 times that of a new refrigerator. Residential pump motors range in size from one half to three horsepower (hp), are operated an average of about four hours per day, but in some cases up to 10 hours per day, and draw approximately one kW per nominal horsepower. Figure 1 shows a typical pool pump and motor. A leaf strainer is usually integrated and aids in priming the pump when it is installed higher than the pool surface. Pools may use multiple pumps for pool filtration, bottom cleaning (pool sweep), and for operating water jets for adjoining spas.

Figure 2 shows a simplified piping diagram for a pool filtration system. Bottom cleaning systems are usually integrated with the filtration systems and operate on vacuum or pressure supplied by the filter pump. They either operate on the suction side (vacuum) of the filtration piping (such as the bottom crawler type), or on the high pressure side of the pump (such as floating pool sweeps). Since bottom cleaning ("pool sweep") systems require full flow to operate properly, low speed operation of two-speed pumps can inhibit their function. High-pressure cleaning systems sometimes employ separate pumps to provide water pressure, but this practice is becoming less common.

Figure 1: Typical Pool Pump with Leaf Strainer

Figure 2: Simplified Piping Diagram for a Pool Filtration System.



Three types of filter media are commonly used. Sand filters remove particles down to 25 microns (μ or micrometers) and are cleaned by back washing. Cartridge filters remove particles down to approximately 15μ and are cleaned by removing the cartridge and spraying it down. Diatomaceous earth (DE) filters remove particles down to 3μ and can also be back-washed (ADM 2001). Sand filters require the most pump pressure, followed by diatomaceous earth and cartridge filters.

3 Market Status

3.1 Market Penetration and Sales

Market saturation varies geographically. About 8 percent of households in the PG&E service area have pools (PG&E 2002b), whereas about 11 percent in SCE territory have pools (CEC 1992). Table 1 compares estimates of pool populations in California from four sources.

Table 1: Estimates of Pool Populations in Major Utility Areas

Utility Service Area	CEC 2000 SF/MF/MH*	CEC 1992 SF/MF/MH	CEC 1992 SF only	ADM 2001 SF only
PG&E	n.a.	242,800	217,587	133,476
SCE	n.a.	361,654	335,857	323,403
LA (non-SCE)	n.a.	140,514	126,463	26,613
SDG&E	n.a.	85,486	77,255	57,634
SMUD	n.a.	46,603	43,996	35,085
BGP	n.a.	17,253	15,785	n.a.
Totals	1,119,005	894,310	816,943	576,211

*SF single-family, MF multi-family, MH mobile homes

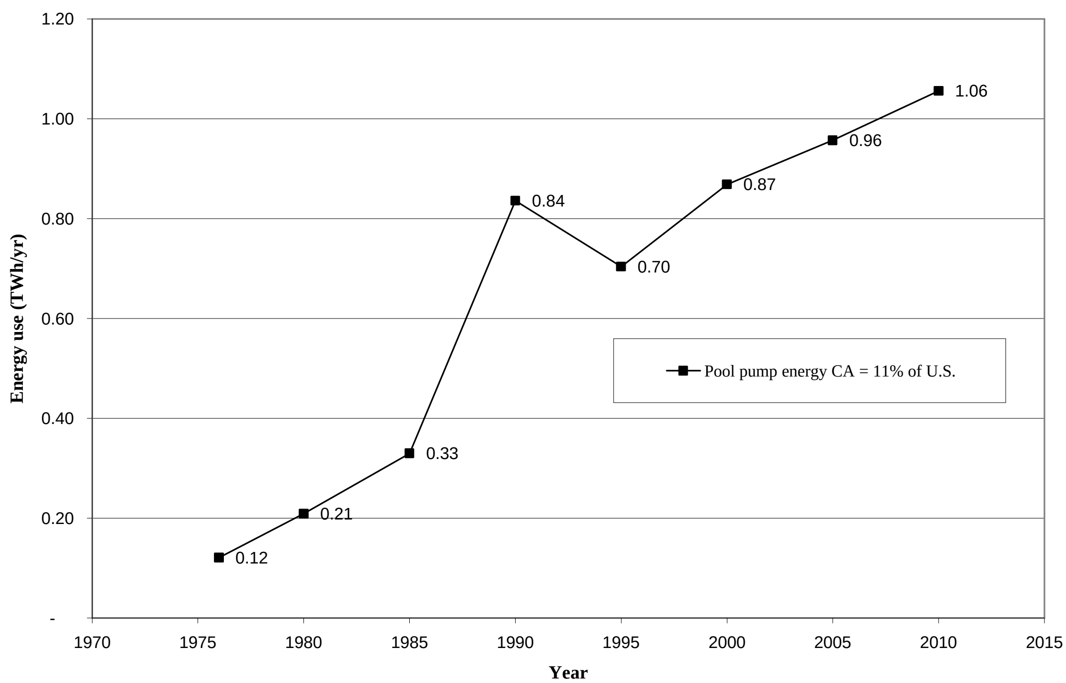
The 1992 CEC data (CEC 1992) is from a statistical survey of residential energy users and appliances including pool pumps and includes data from surveys conducted in 1989 and earlier, whereas the 2000 CEC data (CEC 2000) is probably most accurate. The survey classified pools as single-family, multi-family, and mobile home, all of which use similar equipment. The 2000 CEC survey data is more representative of current market penetration. The ADM data is from a 2001 market study that studied swimming pool pumps in five service areas of California, but population estimates reported are lower than from the other surveys. PG&E's believes it has 320,000 pools in its service territory. Based on the 2000 CEC data about 9.8 percent of the 11,362,903 residences in California, or 1,114,000 have swimming pools. Since the CEC study was done, this has probably grown to nearly 1.2 million, private, residential, in-ground pools in the state.

3.2 Sales Volume

Most sales are for replacements. Pool pumps and motors have an average service life of ten years (DOE 2001), so the current annual replacement volume is about 1/10th of the total number of pools, or about 120,000 units per year. The CEC predicts an annual growth of pool pump sales averaging 22,700 (CEC 2000), so total sales for replacement and new pumps will be about 142,700 units per year with an annual growth rate of about 1.7%.

National growth in pool pump energy use is expected to continue as shown in Figure 3, which plots the end use energy used by pool pumps from 1976 through 2010 (LBL 1998). Data for 2000 through 2010 are estimates.

Figure 3: Pool Pump Energy End Use (LBL 1998)



3.3 Market Penetration of High Efficiency Options

Manufacturers offer high efficiency pump-motor combinations for most of their product lines, typically using capacitor start, capacitor run motors, but specific pump efficiency data is not generally published by manufacturers and is not available from other sources.

Two-speed pumps offer the greatest opportunity for improving pool filtration efficiency, and their sales volume is easier to ascertain.

In 2001 PG&E instituted a rebate program for residential two-speed motors and pool pumps. They provided 171 rebates in 2001, 352 in 2002, and 969 in 2003. The high growth rate in the number of rebates indicates both increased visibility on the part of the program and improved acceptability of two-speed equipment by contractors. Controls selection, which is critical to preserving energy savings for two speed pumps, is left to the designer or installer.

4 Savings Potential

4.1 Baseline Energy Use

Swimming pool pumps were ranked as the third largest consumer of residential energy in SCE's 1993 *Residential Appliance End Use Study* (SCE 1993). A study by ADM Associates is the most extensive source of field data on pool pumps and their energy use (ADM 2001). ADM found that dedicated pumps for operating pool sweeps have been used in the past, but the present preferred design is to use one pump for both purposes. Therefore, baseline energy use in this report assumes the use the filter pump for both filtration and pool sweeping.

KW demand by individual pumps was measured by ADM and reported as a function of nameplate horsepower (ADM 2001). Averages by utility service area are listed in Table 2. The ADM data suggest that 1 kW per HP is a reasonable baseline power value. Unfortunately, ADM did not document the nameplate service factor of the motors. Calculating horsepower from kW (assuming 50% motor-pump efficiency) results in horsepower values consistently lower than nameplate, suggesting that motors are consistently oversized relative to their actual mechanical load.

Table 2: Pool Pump Motor Survey Results by Utility Service Area (ADM 2001)

Utility Service Area	Average Nameplate HP	Average Measured kW	kW/HP	Calculated HP at 0.5 Efficiency
PG&E	1.18	1.28	1.08	0.86
SCE	1.40	1.37	0.98	0.92
SDG&E	1.24	1.42	1.15	0.95
Weighted avg.	1.28	1.36	1.06	0.91

Unit energy consumption (UEC) values, listed in Table 3, vary widely depending on their source. The two lowest UECs (725 and 792 kWh/year), both referenced to the same 1998 study, are national averages, and are probably not representative of California conditions. The two CEC estimates are utility forecasts using conditional demand analysis and so may include other pool-related energy use. From these data it would be safe to assume that annual energy use in California averages 2600 kWh for most residential scale pools.

Table 3: Pool Pump Unit Energy Consumption Estimates

Source	Unit Energy Consumption (kWh/yr)
DOE-2001, p. 62; referenced to ADL-1998.	725
CEC-2000, p. 2 of table.	2,749
EIA-1997, p. 17; also referenced to ADL-1998.	792
PG&E-1994, p. 27.	2,297
DEG-1994, p. 8.	2,220 - 3,980
SCE-1992, a.k.a. RAEUS, p. 6-5.	1,962
SCE-1991, a.k.a. RAEUS, p. 5-8.	2,105
CEC-1991, P300-91-023, forms 2.1.	2,795 - 2,803
RAS-1990, quoted in DEG-1996b, p. 1.	2,622

4.2 Proposed Test Method

Two test methods will need to be used for swimming pool pumps: The Hydraulics Institute Standard *ANSI/HI 1.6-2000: Centrifugal Pump Tes*ts is the appropriate test standard to test the overall efficiency of pump/motor combinations. IEEE 114-2001: *Test Procedures for Single-Phase Induction Motors* is the appropriate test standard for measuring motor efficiency.

The HI 1.6 test is completed over a range of pressure drops to develop curves for flow vs. head and flow vs. power. To develop ratings, the pump curve will be overlaid on a reference system curve to determine the rated flow and energy use. Two reference system curves shall be used to account for high and low head pool designs and for a range of residential pool sizes:

Curve A. $H = 0.0167 \times F^2$

Curve B: $H = 0.050 \times F^2$

Where:

H is the total system head in feet of water.

F is the flow rate in gallons per minute (gpm).

Curve A corresponds to a system which has a flow rate of 60 gpm at 60 feet of head and is typical of new pool construction using 2 inch PVC pipe. Curve B corresponds to a system which has a flow rate of 40 gpm at 80 feet of head and is typical of older pool construction using 1.5 inch copper pipe.

For each curve (A&B), the pump head shall be adjusted until the flow and head lie on the curve. The following shall be reported for each curve and pump speed (two-speed pumps shall be tested at both high and low speeds):

- Head (feet of water)
- Flow (gallons per minute)
- Power (watts and volt amps)
- Energy Factor (gallons per watt hour)

Where the Energy Factor (EF) is calculated as:

EF = Flow (gpm) * 60 / Power (watts)

Reporting an energy factor in units of gallons per watt hour is analogous to other energy factors such as cfm per watt for fans and lumens per watt for lights, and would facilitate quick estimates of energy use. For example:

High Speed: 25,000 gallon pool x 1 turnover per day / 2 gal/Wh = 12.5 kWh per day

Low Speed: 25,000 gallon pool x 1 turnover per day / 5 gal/Wh = 5 kWh per day

4.3 Efficiency Measures

Pump efficiency varies with flow rate and head; the pool designer should select a pump that has an optimal efficiency that occurs at a flow rate that is close to the design flow rate for the particular pool system. Further, the design flow rate should be chosen to be no fewer than 8 hours per day for residential private pools. In addition to applying proper design practice, there are two approaches to improving efficiency that may be regulated by Title 20. These include high efficiency pump-motor combinations, and using pumps with two-speed motors.

Since overall pump efficiency is the product of motor and pump (impeller and volute) efficiency, both more efficient motors and more efficient pumps can be used to improve overall efficiency. In its Technical and Ecological Services report, PG&E refers to efficiency as “wire-to-water” efficiency, which is the energy imparted to the water (flow and head) divided by electrical energy input (PG&E 2002). A variety of pumps tested by PG&E had wire-to-water efficiencies ranging from 23% to 53%. As noted above, a better measure of overall system efficiency would be gallons per watt hour. This measure takes into account overall system hydraulic effects, which are much more significant than the motor and pump efficiencies alone.

Although pumps are sold as a unit, motors are obtained from OEM manufacturers and their efficiency ratings should be readily available. Residential pool pumps use one of three types of single phase capacitor motors: capacitor start (also known as capacitor start induction run), permanent split capacitor (PSC) (also known as single value capacitor), and capacitor start capacitor run (also known as two-value capacitor). General efficiency ranges are shown in Table 4.

Table 4: Motor Efficiencies

Type	Efficiency Range (%)
Capacitor Start	40 – 50
Permanent Split Capacitor	45 – 55
Capacitor Start Capacitor Run	55 – 70

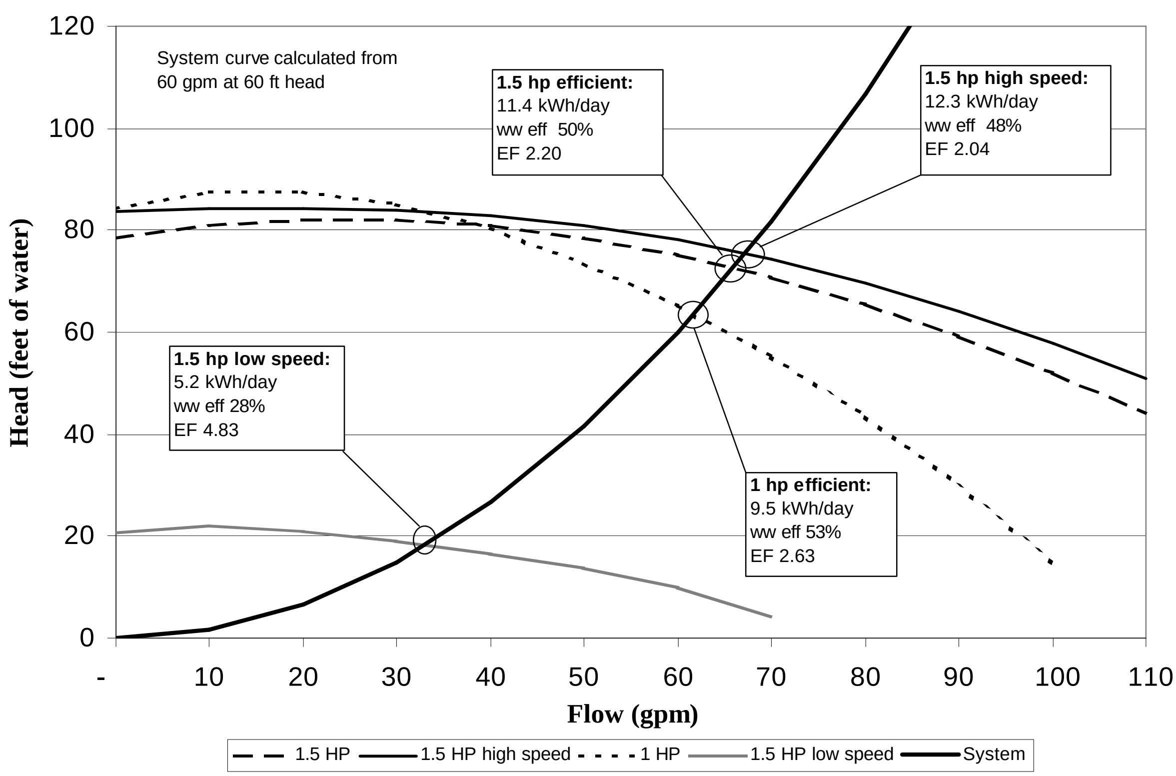
Source: (Eliot 2004)

Using pumps with two-speed motors offer the most significant opportunity for energy savings by taking advantage of pump affinity laws, that state that the power consumed by a pump is proportional to the cube of the flow rate. In other words, if a pump’s flow rate is reduced by half, its power draw is reduced to one eighth. Operating a pump equipped with a two-speed motor at half speed for twice as long therefore moves the same volume of water, but in theory uses only one-quarter the amount of energy. In reality, two-speed motors are less efficient at the lower speed and the cube law does not hold for systems with orifices, so energy savings are closer to 55%. Annual savings ranged from 1,000 to 1,930 kWh for five two-speed pumps tested under a Southern California Edison study (DEG 1994). Low speed operation is generally adequate for filtering, but high speed is needed for operating pool sweeps for a few hours daily, and for plating DE filters after backwashing.

Specialized controls are needed for two-speed pumps to schedule the appropriate amount of low speed operation for filtration and high speed operation for cleaning. High speed operation may also be required for startup to ensure that the pump is properly primed, particularly when it is installed above the pool water level or for solar heated pools. Controls should provide for temporary manual override of low speed operation. Controls could integrate control of solar pool heating systems as an option. At least four manufacturers of controls provide two-speed control and high speed start-up, including Pentair, Aqualink, Wailani, and Independent Pool Products. Intermatic's low-cost electronic timer may be programmed to start on high speed, then drop back to low speed.

Figure 4 compares performance and efficiency for three pumps, one operated at two different speeds. The "system curve", which begins at the origin and rises exponentially with flow rate, is specific to the pool piping and filter pressure drop characteristics. The point at which a pump curve crosses the system curve is the operating point, or the flow the pump can be expected to deliver. To facilitate comparison, Figure 4 lists the wire-to-water efficiency, the energy factor in gallons per watt hour, and the daily energy use based on a 25,000 gallon daily turnover.

Figure 4: Pump Curves and System Curve



Source: TES 2002

The 1.5 HP efficient pump uses 7% less energy than the standard model and requires only slightly more time to turn over the 25,000 gallon volume. The 1 HP efficient pump uses 23% less energy and requires an additional 33 minutes of operation to accomplish the same turnover. The 1.5 HP standard pump operated at half speed uses the least energy of all (58% savings), but requires twice the time. Low speed pump operation must also be mixed with high speed operation in order to operate the pool sweep equipment. In this particular comparison, the best choice is the two-speed, provided it is run on high speed for an hour or two to operate the pool sweep. Second choice might be the 1 HP efficient pump, which provides less savings.

It should be noted that the efficiency of the 1.5 HP two-speed pump is just slightly less (at high speed) than that of the so-called "efficient" pump, raising the question of whether pumps sold as "efficient" just move less water. Also, the wire-to-water efficiency of the 1.5 HP two-speed pump falls from 48% to 28% when operated at low speed due to the drop in motor efficiency.

Pump (impeller-volute) efficiency can be determined by testing, but is seldom reported and is not regulated by state or federal standards. Unlike motor efficiency, pump efficiency varies substantially with load. Table 5, which lists PG&E test results for a 1.5 HP "efficient" pump, compares overall (wire-to-water) efficiency at a variety of flow rates as affected by changing head pressure. Peak pump efficiency occurs at a flow of 70-80 GPM, but the energy factor is highest at the lowest head.

Table 5: 1.5 HP Pump Test Results

Head (feet)	Flow (gpm)	Wire-to-Water Efficiency	Energy Factor (gal/Wh)
82	20	25%	0.95
82	30	33%	1.29
81	40	40%	1.59
78	50	45%	1.84
75	60	49%	2.07
71	70	51%	2.29
65	80	51%	2.50
59	90	50%	2.72
52	100	48%	2.96
44	110	45%	3.24
35	120	40%	3.59

The efficiency of pool pump and filter systems can also be improved by properly matching pumps to system flow and pressure head requirements. Proper system sizing falls under the jurisdiction of Title 24 instead of Title 20. However, changing the way pumps are labeled (using "horsepower" and "service factor") could reduce confusion about actual size, encourage improved sizing, and can be addressed by Title 20.

Service factor is a measure of how much a pump motor can be under-sized without overloading the motor. For example, a 1 HP pump with a service factor of 2.0 draws about the same power as a two-horsepower pump with a service factor of 1.0. The reasons for marketing high service factor pumps are unclear, but the practice creates confusion and could be contributing to inappropriate pump sizing. Service factor is discussed in greater detail in Appendix A.

4.4 Standards Options

A performance standard using energy factor could be set to eliminate particularly poor performers from the market. Some accommodations may need to be made for special purpose pumps, such as high head pumps used with pools that incorporate water features, or that may be needed for pool cleaning equipment that requires higher than normal head pressures. However, there is little data currently available and few agreed upon standards. A prescriptive standard is possible for motors as motor type is easily defined and high efficiency models are available in all sizes.

A simple and potentially effective standards measure would be to require that all pumps and controls sold for swimming pool applications have dual speed capability. Two-speed pumps are available from at least six manufacturers, and standardization of motor frame sizes makes it relatively easy for manufacturers to add two speed motors to their product lines. While energy savings would depend on how the pump is controlled, this measure would give every pool owner the opportunity to take advantage of low speed energy savings and should inspire installation of compatible controls.

The use of smaller size pumps and operating them for more hours is a valid energy efficiency measure, but Title 20 cannot regulate the size of pump used for a particular pool. Requiring pump sizing documentation similar to that required for heating and cooling systems should be considered as a possible Title 24 measure.

Requiring pump testing and publication of certified energy factors would greatly improve the pool designer's and pool owner's ability to select more efficient pumps and would provide the data needed for future performance standards. Requiring all pumps to be horsepower rated for continuous duty using a reasonable service factor would eliminate the possibility of improper replacements, for example replacing a 1 HP service factor 1 pump with a 1 HP service factor 2 pump could double the energy consumption of a pool system.

4.5 Energy Savings

Energy savings impacts resulting from elimination of lower performing pumps is difficult to infer from the limited market and test data available. We estimate that elimination of low efficiency motors such as capacitor start would result in a 10% reduction in energy use.

Two-speed pool pump savings are more available. Five residential pools were monitored in 1994-95 under a Southern California Edison research project (DEG 1994, DEG 1996). The original single-speed pumps were retrofitted with two-speed pumps. This five-month monitoring project demonstrated energy savings ranging from 38% to 65%. Demand savings were 71% to 73%.

Given the variability in how pump controls might be implemented, energy savings would likely range from 20% to 60%, and would probably average about 40%. State wide energy savings would average more than 1040 kWh per pool per year, or 1000 GWh if all pools in the state were equipped with two speed pumps. Efficiency programs and/or Title 24 requirements to insure correct use of controls would have a significant impact on improving these savings.

The value of energy savings from improved labeling depends on how the market would respond to reliable comparative performance data, and is impossible to quantify without obtaining more performance and market data than is presently available.

5 Economic Analysis

5.1 Incremental cost

The incremental cost of a “high-efficiency” pump and motor over a standard efficiency model varies from $60 (1 hp) to $110 (2 hp) (Hayward Super Pump II). The actual OEM cost of the two-value capacitor and switch is estimated to be about $15. Although there are no efficiency data presented in the catalogs, most “high-efficiency” pumps are assumed to be capacitor start, capacitor run motors, and it is presumed that manufacturers rely on value pricing alone to sell so-called "high efficiency" pumps.

The incremental cost for two-speed vs. one-speed pumps, according to PG&E, ranges from $215 to $300. An Internet search showed that the incremental cost of two-speed pumps over similar one-speed models varied from $70 to $100 (Sta-Rite Duraglas and Hayward Super Pump II) to $170 (Purex Whisperflow) for 1 hp to 2 hp pumps. The difference between these two price ranges is probably wholesaler and contractor markup. The incremental cost of a two-speed pump and control in either a new pool or retrofit is estimated to be $579.

The imposition of testing and labeling requirements will have an indeterminate cost that is likely to be passed on by the manufacturer to the consumer, but will be spread over a very large sales volume.

5.2 Design life

The average service life of swimming pool pumps is ten years (DOE 2001). Testing or labeling would not affect design life. No data are available to determine whether low speed operation extends or shortens motor life. Since motor life is principally determined by speed and heat, one might speculate that a two-speed motor operating at low speed would last longer, since the speed and heat would be reduced.

5.3 Life Cycle Cost

The life cycle cost for high efficiency and two-speed pool pumps is provided in Table 6, and was calculated using the standard California Energy Commission methodology. Present value of annual energy savings is calculated per California Energy Commission 2000 Appliance Standards - Life Cycle Cost Analysis document Table 1A.

Table 6: Analysis of Customer Net Benefit

Motor Option	*Design Life (years)*	*Annual Energy Savings (kWh)*	*Present Value of Energy Savings**	*Incremental Cost*	*Net Customer Present Value***
High Efficiency	10	260	$242	$85	$157
Two-speed	10	1,040	$968	$579	$389

*Present value of energy savings calculated using a Life Cycle Cost of $0.931/kWh (CEC 2001).
**Positive value indicates a reduced total cost of ownership over the life of the appliance

6 Acceptance Issues

Stakeholders include pool equipment manufacturers, motor manufacturers, pool equipment distributors, and pool service companies. Industry associates that serve sectors of the pool industry include NSPI (National Spa and Pool Institute), NSPF (National Swimming Pool Foundation), PPOA (Professional Pool Operators of America), IPSSA (Independent Pool & Spa Service Association), and SPEC (California Spa and Pool Industry Education Council).

The pool industry is primarily represented by the National Spa and Pool Institute (NSPI), Alexandria, VA. The local representative's position is that two-speed pumps create a challenge in that controls require an extra wire and a licensed electrician to install it. Most pool contractors do not have this license, but contractors license law typically allows tradesmen to do work outside of their trade provided it is directly related to their work. He favors changing out older oversized motors and pumps for smaller and therefore more efficient sets.

The NSPF is a non-profit research foundation based in Merrick, NY. Their research interests concern pool and diving safety. They have a program to train and certify pool operators. They accept applications for research on pool-related topics and might be a resource for educational work.

The PPOA has approximately 1,000 members from the large pool and water park sector. Their own description is that "(t)he Professional Pool Operators of America, known simply as PPOA, is uniquely dedicated to improving the lot of the one who maintains the structure, the hardware and the water that makes it all happen." This sector is not the target of the residential two-speed market, but might offer an audience more receptive to "new" technology.

The IPSSA is an organization of smaller pool service firms. They have ten chapters, eight of them in California. These chapters have monthly meetings and could offer a venue for educational presentations. Their representative related that pool service firms do not like two-speed pumps because they make pool maintenance more complicated, presumably because of the difficulty of overriding low speed operation with some control systems.

SPEC is a statewide umbrella trade association which promotes the spa and pool industry while educating the public, local and state regulatory, and legislative bodies on spa and pool related issues. Every local, regional and national pool and spa trade association active in California has an official representative serving on SPEC's Board of Governors.

The Master Pools Guild[1] lists the most experienced builders and offers a short list of firms that could lead the rest of the industry if convinced of the value of two-speed systems.

A comprehensive list of organizations in the swimming pool sector that includes 65 manufacturers of spas and hot tubs is located at: .http://www.perfectpoolandspa.com/poolcarelinksbottom.html.

6.1 Infrastructure issues

Six manufacturers produce 15 models of two-speed pumps and motors that are certified under the PG&E rebate program that are likely to meet most of the requirements for conventional pools. These range in nameplate power from 0.75 HP to 2.5 HP.

Two speed controls, required for proper control of two-speed pumps, are currently available. Five manufacturers were identified, including Pentair, Aqualink, Wailani, Independent Pool Products, and Intermatic.

A barrier identified by PG&E is the lack of consumer education on the benefits of two-speed pumps and other efficiency measures. However, some manufacturers indicated to PG&E in 2001 that they would be willing to provide training for industry, service contractors, and builders.

Efforts by Davis Energy Group to locate a contractor to retrofit a two-speed pump revealed current limitations of two-speed pump implementation. Vendors willing to sell two-speed pumps were located, but none of these vendors could recommend a contractor for the work (in the Auburn/Grass Valley area). A telephone survey of several pool installers and pool service firms indicated they were not interested or did not have aptitude for the work. The one firm with experience in two-speed pumps advised that it was a poor investment. Pump affinity laws do not appear to be generally understood or appreciated by the pool service industry. Industry education, and programs to make consumers aware of willing vendors and the importance of improved controls, would enhance the impact of a two-speed pump standard.

6.2 Existing Standards

Special purpose single phase motors such as used in residential pool pumps are not currently regulated by state or federal standards. Pools and related equipment are regulated by a number of voluntary standards. Standard NSF/ANSI 50-2001 (ANSI 2001) includes a test for single-speed centrifugal pumps. The purpose of this test is to verify the manufacturer's pump curve. Standard ANSI/HI 1.6-2000 (ANSI 2000) includes a test for centrifugal pumps. ANSI/UL 1081 “Standard for Swimming Pool Pumps, Filters, and Chlorinators” is mentioned in ANSI/NSPI-5 (NSPI 1995), “Residential In-Ground Swimming Pools.” We have not identified any existing standards for two-speed pumps.

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[1] : http://www.masterpoolsguild.com/locations.asp#California

California Title 24, Part 6, Section 114 (b) 3. states:

> The pool shall have directional inlets that adequately mix the pool water; and
>
> The circulation pump shall have a time switch that allows the pump to be set to run in the off-peak electric demand period, and for the minimum time necessary to maintain the water in the condition required by applicable public health standards.

EXCEPTION to Section 114 (b) 3 B: Where applicable public health standards require on-peak operation.

7 Recommendations

7.1 Recommended Standards Options

Four Title 20 code changes are proposed. The first proposal is to require testing and listing of all single phase pool pumps ranging from 1/2 HP to 3 HP sold in California. Flow, power, and energy factor listings at two system curves are recommended to facilitate a range of residential pool sizes and flow requirements. For two-speed pumps, listings would include both high speed and low speed.

The second proposal is to require a uniform horsepower rating of all single phase pool pumps in order to provide the consumer and contractor with clear information. We recommend using a continuous duty service factor of not more than that recommended by NEMA standard MG 1-2003 (NEMA 2003). This horsepower rating would be included in the efficiency listing.

The third proposal is to prohibit the sale of low efficiency capacitor start (also known as capacitor start induction run) motors.

The fourth proposal is to prohibit the sale of one-speed, single-phase swimming pool pumps and motors in California. This measure is likely to meet with substantial stakeholder resistance. Our recommendation is to implement this proposal, but to delay implementation until 2008. The testing and listing requirement will improve the market for two-speed and a mandatory standard.

Title 24 improvements should be considered for the 2008 rulemaking to require documented pool pump sizing and to include specification of a minimum pump energy factor. These improvements would be made possible by the adoption of the proposed Title 20 changes. The proposed changes will also support PG&E and other utility pool pump programs by providing data that can be used to gear incentive amounts to pump efficiency.

7.2 Proposed Changes to the Title 20 Code Language

The following standards language is proposed for section 1605.3:

(u) ***Residential Pool Pumps and Controls.***

(1) ***Service Factor****. All pool pump motors sold and installed after January 1, 2006 shall have a service factor not exceeding that specified in NEMA standard MG-1 Table 39.*

(2) ***Motor Efficiency.*** *Pool pump motors sold and installed after January 1, 2006 may not be standard efficiency, capacitor start – induction run type.*

(3) ***Two-speed Capability****.*

a. ***Pump Motors.*** *All pool pump motors with total capacity of 1 HP or more sold and installed after January 1, 2008 shall have the capability of operating at two or more speeds with the low-speed having a maximum of rotation rate of 1/2 of the maximum rotation rate.*

b. ***Pump Controls****. All pool pump motor controls sold and installed after January 1, 2008 shall have the capability of operating the pool pump at least two speeds. The primary circulation speed shall be the low-speed with any high-speed override capability being for a temporary period not to exceed 1 normal on cycle.*

The following standards language is proposed for Table U in section 1606:

Residential Pool Pumps	Motor Service Factor	
	Motor Type	PSC, cap start cap run, ECM, DC, etc
	Motor Speeds	one, two, variable
	Motor Efficiency	
	Rated Horsepower	
	Head (A,B)	
	Flow (A,B)	
	Power (A,B)	
	Energy Factor (A,B)	

8 References

ADM-2001: ADM Associates, *Baseline and Market Characterization Report* (Revised Draft Version), October 2001, prepared for PG&E Contract No. 4600011448.

ASHRAE-2000: ASHRAE Handbook 2000, HVAC Systems and Equipment.

ANSI-2000: ANSI/HI 1.6-2000: Hydraulics Institute Standard 1.6, American National Standard for Centrifugal Pump Tests, 2000.

ANSI-2001: Standard NSF/ANSI 50-2001, Circulation system components and related materials for swimming pools, spas/hot tubs.

CEC-1992: California Energy Commission, *Electricity Report 1992*, P300-91-023.

CEC-2000: California Energy Commission, *California Energy Demand 2000.*

CEC-2002: California Energy Commission, *Proposed Amendments to Title 20 and 24*, Docket No. 01-AB970-APSTD dated January 22, 2002, effective July 1, 2002.

DEG-1994: Davis Energy Group, *Two-Speed Pool Pump Project* for Southern California Edison, December 1994.

DEG-1996: David Springer, Davis Energy Group, and Fred Rohe, Southern California Edison, *Field Studies of Two-Speed and PV-Powered Pumps and Advanced Controls for Swimming Pools*, ACEEE, 1996.

DEG-1996b Home Appliance Energy Consumption Background Information, DEG, February 1996.

DHS-1986: Dept. of Health Services, State of Ca., *The Design, Construction, Operation, and Maintenance of Public Swimming Pools*, Ca. Health and Safety Code, 1986.

DOE-2001: Department of Energy, Office of Building Research and Standards, *2002 Priority Setting for New Products*, October 26, 2001.

EIA-1997: *A Look at Residential Energy Consumption in 1997*, Energy Information Administration, 1997.

LBL-1998: Report LBNL-40295, *Miscellaneous Electricity Use in the U.S. Residential Sector*, April 1998.

Marks 1996: Marks Standard Handbook for Mechanical Engineers, Tenth Edition, McGraw, 1996.

NEMA, 2003. ANSI/NEMA MG 1-2003: *Motors and Generators*. National Electrical Manufacturers Association. Rosslyn, VA, 2003.

NSPI-1995: ANSI/NSPI-5, *Standard for Residential In-Ground Swimming Pools*, National Spa and Pool Institute, 1995.

PG&E-2000: Pacific Gas & Electric, *Swimming Pool Pump Operating Practices*, December 2000.

PG&E-2002:http://www.pge.com/003_save_energy/003a_res/123cashback/r_pool_tips.shtml

PG&E-2002b: http://www.pge.com/003_save_energy/003a_res/pdf/res.pdf.

RAS-1990: RASS Study, PG&E, 1990.

RES-1994: Residential Energy Survey, 1994.

Riv-0000: Riverside County, Public Pool and Spa Operators' Guide, no date.

SCE-1991*: 1991 Residential Appliance End Use Survey*, Quantum Consulting, November 1992.

SCE-1992*: 1992 Residential Appliance End Use Study*, Quantum Consulting, Dec 1993.

Appendix A: Pump Service Factors

Marks' Handbook of mechanical engineering gives the following discussion of service factor. "The service factor of an alternating current motor is a multiplier applicable to the horsepower rating. When so applied, the result is a permissible horsepower loading under the conditions specified for the service factor. When operated at service factor load with service factor of 1.15 or higher, the permissible temperature rise by resistance is as follows: class A insulation, 70ºC; class B, 90ºC; and class F, 115ºC." (Marks-1996, p. 15-44). This rating is at an ambient maximum of 40ºC (104ºF); if it is higher, then the acceptable temperature rise should be reduced. There are no other insulation classes than A, B, and F (NEMA MG-1, Table 38).

The service factor of commercial grade motors is usually 1.15 with an occasional 1.00 or 1.20. Designers size the nominal (nameplate) horsepower of the motor to match the expected load and credit the extra 15% towards a safety factor (1.15 minus 1.00). This safety factor is spare capacity, but good engineering practice in view of the tolerances in manufacturing.

The service factor of residential grade pumps and motors has taken a different meaning. Service factors of 1.5 are common and 1.65 is found exceptionally. This service factor is so large that the interval can include two motors of different nominal rating. The result is confusion on the part of the buyer. Industry observers trace the origin back to one California pool company that gained a business advantage by quoting all of its installations with "up-rated" motors, i.e., a smaller motor with a bigger nameplate and a smaller price. This practice has become the lowest common denominator in an imperfect market.

Some vendors now quote a one-speed pump and motor with a low service factor (i.e., a standard motor called "full-rated") and an "equivalent" two-speed version with a higher service factor (i.e., a smaller motor called "up-rated"). Thus the full-rated 1-hp motor will be physically larger than the up-rated 1-hp version, which might be a full-rated 0.75 hp motor.

NEMA Standard MG-1 says this about service factor:

> "When operated at rated voltage and frequency, general purpose alternating-current motors of the open type shall have a service factor in accordance with Table 39. [MG1-12.51.1 and MG1-14.37] When an induction motor is operated at any service factor greater than 1.0, it may have efficiency, power factor, and speed different from those at rated load. Locked-rotor torque and current and breakdown torque will remain unchanged. A motor operating continuously at any service factor greater than 1.0 will have a reduced life expectancy compared to operating at its rated nameplate horsepower. [MG1-14.37]
>
> In those applications requiring an overload capacity, the use of a higher horsepower rating is recommended to avoid exceeding the temperature rises for the class of insulation system used and to provide adequate torque capacity [MG1-12.51.2]" (Section 9.15)

The NEMA document states clearly that an up-rated motor will have a shorter service life, all other things being equal, than a full-rated motor. Thus, the current practice amounts to poor design engineering and probably poor business practice, as well. It would be a service to consumers and to economic efficiency to ban the practice of the up-rated or high-service-factor motor.

An acceptable limit on service factor would be the Table 39 values mentioned in the excerpt above. These values are service factors of 1.15 for most of the pool application AC motors. It allows a service factor of 1.25 for “small motors” including 0.5 hp, 0.75 hp, and 3600 rpm 1-hp nominal. Use of these values would eliminate the worst of the bad actors.

TABLE 39 of NEMA MG1. SERVICE FACTORS OF GENERAL-PURPOSE ALTERNATING-CURRENT MOTORS OF THE OPEN TYPE [MG1 TABLE 12-4]

	Synchronous Speed, Rpm							
HP	**3600**	**1800**	**1200**	**900**	**720**	**600**	**514**	
1/4	1.35	1.35	1.35	1.35	—	—	—	
1/3	1.35	1.35	1.35	1.35	—	—	—	Small Motors
1/2	1.25	1.25	1.25	1.15*	—	—	—	
3/4	1.25	1.25	1.15*	1.15*	—	—	—	
1	1.25	1.15*	1.15*	1.15*	—	—	—	
1.5-125	1.15*	1.15*	1.15*	1.15*	1.15*	1.15*	1.15*	
150	1.15*	1.15*	1.15*	1.15*	1.15*	1.15*	—	
200	1.15*	1.15*	1.15*	1.15*	1.15*	—	—	
250	1.0	1.15*	1.15*	1.15*	—	—	—	Medium Motors
300	1.0	1.15*	1.15*	—	—	—	—	
350	1.0	1.15*	1.15*	—	—	—	—	
400	1.0	1.15*	—	—	—	—	—	
450	1.0	1.15*	—	—	—	—	—	
500	1.0	1.15*	—	—	—	—	—	

*In the case of polyphase squirrel-cage motors, these service factors apply to Design A, B, and C motors.